

What is claimed is:

1.           A limit cycle autotuning method of calculating  
2 a control parameter by alternately performing operation  
3 of outputting a predetermined heat-side manipulated  
4 variable set point to a heating actuator and operation  
5 of outputting a predetermined cool-side manipulated  
6 variable set point to a cooling actuator in a heat/cool  
7 control apparatus which performs temperature control by  
8 performing feedback control computation with respect to  
9 a deviation between a set point and a controlled  
10 variable on the basis of the control parameter, and  
11 properly switching a heat mode of outputting a  
12 manipulated variable to the heating actuator and a cool  
13 mode of outputting a manipulated variable to a cooling  
14 actuator, comprising:  
15           the first limit cycle generation step of  
16 generating a first limit cycle of alternately outputting  
17 the heat-side manipulated variable set point and the  
18 cool-side manipulated variable set point;  
19           the first control response detection step of  
20 detecting a first control response corresponding to the  
21 first limit cycle;  
22           the second limit cycle generation step of  
23 generating a second limit cycle by changing one of the  
24 heat-side manipulated variable set point and the  
25 cool-side manipulated variable set point on the basis of

26 predetermined change instruction information for  
27 instructing which one of the heat-side manipulated  
28 variable set point and the cool-side manipulated  
29 variable set point is to be changed after the first  
30 limit cycle and a predetermined manipulated variable  
31 change ratio indicating a degree of the change;  
32               the second control response detection step of  
33 detecting a second control response corresponding to the  
34 second limit cycle; and  
35               the control parameter calculation step of  
36 calculating the control parameter for each of the heat  
37 mode and the cool mode on the basis of the detected  
38 first and second control responses.

2.           A limit cycle autotuning method of calculating  
2 a control parameter by alternately performing operation  
3 of outputting a predetermined heat-side manipulated  
4 variable set point to a heating actuator and operation  
5 of outputting a predetermined cool-side manipulated  
6 variable set point to a cooling actuator in a heat/cool  
7 control apparatus which performs temperature control by  
8 performing feedback control computation with respect to  
9 a deviation between a set point and a controlled  
10 variable on the basis of the control parameter, and  
11 properly switching a heat mode of outputting a  
12 manipulated variable to the heating actuator and a cool  
13 mode of outputting a manipulated variable to a cooling

14 actuator, comprising:  
15           the first limit cycle generation step of  
16 generating a first limit cycle of alternately outputting  
17 the heat-side manipulated variable set point and the  
18 cool-side manipulated variable set point;  
19           the first control response detection step of  
20 detecting a first control response corresponding to the  
21 first limit cycle;  
22           the manipulated variable change ratio  
23 calculation step of determining, on the basis of the  
24 first control response, change instruction information  
25 for instructing which one of the heat-side manipulated  
26 variable set point and the cool-side manipulated  
27 variable set point is to be changed after the first  
28 limit cycle and a manipulated variable change ratio  
29 indicating a degree of the change;  
30           the second limit cycle generation step of  
31 generating a second limit cycle by changing one of the  
32 heat-side manipulated variable set point and the  
33 cool-side manipulated variable set point on the basis of  
34 the change instruction information and the manipulated  
35 variable change ratio;  
36           the second control response detection step of  
37 detecting a second control response corresponding to the  
38 second limit cycle; and  
39           the control parameter calculation step of  
40 calculating the control parameter for each of the heat

41 mode and the cool mode on the basis of the detected  
42 first and second control responses.

3.           A method according to claim 1, wherein  
2           the feedback control computation includes PID  
3 control computation based on the control parameter  
4 including a proportional band, an integral time, and a  
5 derivative time,  
6           in the first control response detection step,  
7 a first amplitude of a controlled variable is detected  
8 as the first control response,  
9           in the second control response detection step,  
10 a second amplitude of a controlled variable, a heat-side  
11 elapsed time from the instant at which output of a  
12 manipulated variable set point is switched to a heat  
13 side to the instant at which the controlled variable  
14 reaches a minimum value, and a cool-side elapsed time  
15 from the instant at which output of a manipulated  
16 variable set point is switched to a cool side to the  
17 instant at which the controlled variable reaches a  
18 maximum value are detected as the second control  
19 response, and  
20           in the control parameter calculation step, a  
21 ratio between a heat-side process gain and a cool-side  
22 process gain is obtained on the basis of the first and  
23 second amplitudes, the proportional band is calculated  
24 for each of the heat mode and the cool mode from the

25 ratio, and the integral and derivative times common to  
26 the heat mode and the cool mode are calculated from an  
27 average of the heat-side elapsed time and the cool-side  
28 elapsed time.

4. A method according to claim 2, wherein  
2 the feedback control computation includes PID  
3 control computation based on the control parameter  
4 including a proportional band, an integral time, and a  
5 derivative time,  
6 in the first control response detection step,  
7 a first amplitude of a controlled variable, a heat-side  
8 maximum deviation set when the controlled variable  
9 reaches a maximum value, and a cool-side maximum  
10 deviation set when the controlled variable reaches a  
11 minimum value are detected as the first control  
12 response,  
13 in the second control response detection step,  
14 a second amplitude of a controlled variable, a heat-side  
15 elapsed time from the instant at which output of a  
16 manipulated variable set point is switched to a heat  
17 side to the instant at which the controlled variable  
18 reaches a minimum value, and a cool-side elapsed time  
19 from the instant at which output of a manipulated  
20 variable set point is switched to a cool side to the  
21 instant at which the controlled variable reaches a  
22 maximum value are detected as the second control

23 response,  
24 in the manipulated variable change ratio  
25 calculation step, the change instruction information and  
26 the manipulated variable change ratio are determined on  
27 the basis of the heat-side maximum deviation and the  
28 cool-side maximum deviation, and  
29 in the control parameter calculation step, a  
30 ratio between a heat-side process gain and a cool-side  
31 process gain is obtained on the basis of the first and  
32 second amplitudes, the proportional band is calculated  
33 for each of the heat mode and the cool mode from the  
34 ratio, the integral and derivative times in the heat  
35 mode are calculated from the heat-side elapsed time, and  
36 the integral and derivative times in the cool mode are  
37 calculated from the cool-side elapsed time.

5. A heat/cool control apparatus which has a  
2 limit cycle autotuning function of calculating a control  
3 parameter by alternately performing operation of  
4 outputting a predetermined heat-side manipulated  
5 variable set point to a heating actuator and operation  
6 of outputting a predetermined cool-side manipulated  
7 variable set point to a cooling actuator, and performs  
8 temperature control in normal operation by properly  
9 switching a heat mode of outputting a manipulated  
10 variable to the heating actuator and a cool mode of  
11 outputting a manipulated variable to the cooling

12 actuator, comprising:  
13                   control computation means for calculating a  
14 manipulated variable to the heating actuator or the  
15 cooling actuator by performing feedback control  
16 computation with respect to a deviation between a set  
17 point and a controlled variable on the basis of the  
18 control parameter in the normal operation;  
19                   manipulated variable change ratio storage  
20 means for storing in advance change instruction  
21 information for instructing which one of the heat-side  
22 manipulated variable set point and the cool-side  
23 manipulated variable set point is to be changed during  
24 the autotuning, and a manipulated variable change ratio  
25 indicating a degree of the change;  
26                   limit cycle generating means for generating a  
27 second limit cycle, during execution of the autotuning,  
28 by changing one of the heat-side manipulated variable  
29 set point and the cool-side manipulated variable set  
30 point on the basis of the change instruction information  
31 and the manipulated variable change ratio after  
32 generating a first limit cycle of alternately outputting  
33 the heat-side manipulated variable set point and the  
34 cool-side manipulated variable set point;  
35                   control response detection means for detecting  
36 a first control response corresponding to the first  
37 limit cycle and a second control response corresponding  
38 to the second limit cycle; and

39 control parameter calculation means for  
40 calculating the control parameter for each of the heat  
41 mode and the cool mode on the basis of the detected  
42 first and second control responses, and setting the  
43 calculated control parameters in said control  
44 computation means.

6. An apparatus according to claim 5, comprising  
2 manipulated variable change ratio calculation means for  
3 determining the change instruction information and the  
4 manipulated variable change ratio on the basis of the  
5 first control response, in place of said manipulated  
6 variable change ratio storage means.

7. An apparatus according to claim 5, wherein  
2 said control computation means performs PID  
3 control computation on the basis of the control  
4 parameter including a proportional band, an integral  
5 time, and a derivative time,  
6 said control response detection means detects  
7 a first amplitude of a controlled variable as the first  
8 control response, and detects a second amplitude of a  
9 controlled variable, a heat-side elapsed time from the  
10 instant at which output of a manipulated variable set  
11 point is switched to a heat side to the instant at which  
12 the controlled variable reaches a minimum value, and a  
13 cool-side elapsed time from the instant at which output



14 of a manipulated variable set point is switched to a  
15 cool side to the instant at which the controlled  
16 variable reaches a maximum value as the second control  
17 response, and  
18           said control parameter calculation means  
19 obtains a ratio between a heat-side process gain and a  
20 cool-side process gain on the basis of the first and  
21 second amplitudes, calculates the proportional band for  
22 each of the heat mode and the cool mode from the ratio,  
23 and calculates the integral and derivative times common  
24 to the heat mode and the cool mode from an average of  
25 the heat-side elapsed time and the cool-side elapsed  
26 time.

8.           An apparatus according to claim 6, wherein  
2           said control computation means performs PID  
3 control computation on the basis of the control  
4 parameter including a proportional band, an integral  
5 time, and a derivative time,  
6           said control response detection means detects  
7 a first amplitude of a controlled variable, a heat-side  
8 maximum deviation set when a controlled variable reaches  
9 a maximum value, and a cool-side maximum deviation set  
10 when a controlled variable reaches a minimum value as  
11 the first control response, and detects a second  
12 amplitude of a controlled variable, a heat-side elapsed  
13 time from the instant at which output of a manipulated

14 variable set point is switched to a heat side to the  
15 instant at which the controlled variable reaches a  
16 minimum value, and a cool-side elapsed time from the  
17 instant at which output of a manipulated variable set  
18 point is switched to a cool side to the instant at which  
19 the controlled variable reaches a maximum value as the  
20 second control response,

21               said manipulated variable change ratio  
22 calculation means determines the change instruction  
23 information and the manipulated variable change ratio on  
24 the basis of the heat-side maximum deviation and the  
25 cool-side maximum deviation, and

26               said control parameter calculation means  
27 obtains a ratio between a heat-side process gain and a  
28 cool-side process gain on the basis of the first and  
29 second amplitudes, calculates the proportional band for  
30 each of the heat mode and the cool mode from the ratio,  
31 calculates the integral and derivative times in the heat  
32 mode from the heat-side elapsed time, and calculates the  
33 integral and derivative times in the cool mode from the  
34 cool-side elapsed time.